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Clay-based materials as fire protection for timber structures

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Fire safety in timber buildings has been one of the main focuses of building regulations due to its combustibility. The design principles provide that structures must satisfy the requirements for their fire resistance in order to meet the load-bearing capacity (R) and compartmentation (EI) criteria for a required period of time. Consequently, the fire performance of building materials is an essential design factor to be considered with.

In Europe, the fire part of Eurocode 5 (EN 1995-1-2 [1]) provides design principles and application rules for the charring performance of timber structures. As the load-bearing capacity of timber is directly related to its residual cross-section, protection materials can provide the primary fire protection against the charring of timber. Currently design guidelines and standards present a limited number of available protection materials for timber, while in practice predominantly gypsum plasterboards are used.

In the past, however, clay plaster was one of the available building materials for protecting timber structures from direct fire exposure. Nowadays, the combinations of timber and clay-based materials (e.g., clay plaster) are being once again rediscovered due to the growing need for low-carbon building design. Yet, the current guidelines and standards do not include any design parameters for clay-based materials as a fire protection system for timber structures. This hinders their widespread use in practice, for example as an authentic fire protection material in historical buildings.

In the last decades, clay-based materials have mainly been tested and used in straw bale buildings. Various full-scale tests with thick clay plaster systems on straw bales have demonstrated that the plaster can provide effective fire protection ability to the wall assemblies, so the fire resistance of up to 120 minutes can be achieved. Recent research by Küppers (nee Wachtling) [2] has shown that the encapsulation criteria $K_2 60$ could be met by combining a light-weight clay board with clay plaster (55 mm in total thickness); additionally, effective thermal properties for clay plaster and board have been determined for numerical simulations.

Over the last years, an extensive investigation by Liblik [3] has been carried out to determine the fire design parameters for traditional type of clay plaster systems in accordance with EN 1995-1-2. Through small-scale tests and intermediate scale furnace experiments conducted at TalTech, RISE, Sweden and TU Braunschweig, Germany, relevant data on the charring performance of timber behind the clay plaster were obtained. The charring performance of timber was mainly influenced by the thickness of plaster. The tests demonstrated that the clay plaster systems remain significantly longer in place in walls compared to its position in ceilings. Two distinct types of failure modes for the clay plaster were determined: i) failure of the mechanical fastening system (when plaster carrier is used), ii) loss of adhesion between the plaster and its substrate (no plaster carrier used). Based on the results, design parameters for clay plaster systems have been proposed and validated by full-scale tests for their implementation into design codes, e.g., prEN 1995-1-2:2022. The proposed design equations represent a conservative design approach for clay boards as a fire protection material based on available fire test results. In addition, the conducted research provides means to rate the fire resistance performance of clay plasters in existing buildings. A framework has been established for expanding the current knowledge to various clay-based materials as a fire protection system, including product development in small-scale [4].

References:

[1] EN 1995-1-2: 2004. Eurocode 5: Design of timber structures- Part 1-2: General-Structural fire design, European Committee for Standardization, CEN.

[2] Wachtling, J., Hosser, D. & Zehfuß, J. (2013) Fire protection of multi-storey straw bale buildings, Research and Applications in Structural Engineering, Mechanics and Computation – Zingoni (Ed.), Taylor & Francis Group, London, ISBN 978-1-138-00061-2.

[3] Liblik, J. & Just, A. (2020) Fire protection provided by clay and lime plasters, Wood Material Science and Engineering. DOI: 10.1080/17480272.2020.1714726.

[4] Liblik, J & Just, A. (2023) Small-scale assessment method for the fire resistance of historic plaster system and timber structures, Fire and Materials, 47 (1), 62−74. DOI: 10.1002/fam.3069.